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14. ABSTRACT

We have developed an integrated instrumentation to demonstrate and implement a test procedure that enhanced the development of suitable polymeric E-O materials for integrated optics. The material test requirements were based on the fabrication, assembly, and end use product requirements of the material in a device. The sequential test procedure is consist of a series of tests designed to efficiently test and screen materials as they are being developed. The test targets a simple integrated optic device to measure a wide range of performance values, while the compatibility of the material will be evaluated during the fabrication of the test device. The development of an enhanced material system will demonstrate the usefulness of the procedure. The test methods have been transfer to the material development community.

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AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

END-OF-THE-YEAR-REPORT

for

GRANT #, F49620-97-1-0124

Integrated Instrumentation for Electro-optic Polymer Development

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October 1, 2000

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1. Introduction

A major driving force for optical connections is that optical pulses are unaffected by electrical capacitance that delays electrical pulses, allowing operation at higher clock rates. Before optical interconnections become practical, affordable optical switches and fast opto-electronic conversion devices need to be developed. Polymeric nonlinear optical materials offer exciting new opportunities in integrated nonlinear optics. In particular, electro-optic (E-O) polymeric materials exhibit low dispersion and low dielectric constants. E-O polymers have been modulated to 60 GHz and exhibit few fundamental limits for ultra fast modulation and switching. Polymeric integrated optical materials also offer great fabrication flexibility in electronic systems applications. High levels of integration have been demonstrated with polymers by using multiple layers of wave guides as well as in-plane and out-of plane mirrors. The potential for low-cost manufacturing, packaging, and assembly arises from the demonstrated ability to perform hybrid integration of single-mode components using lithographically-defined registration techniques. Advanced products include components for "flight-by-light" and phase array radar applications, opto-isolators for semiconductor test fixture applications, impedance matching fan out modules, processor multichip modules with high bandwidth interfaces between CPU and second-level cache, and 8-12 bit, high-speed A-D's. Electro-optic polymers are unique in offering this level of product potential. However, despite the exciting promise of these materials, only laboratory demonstrations have occurred.

A number of different groups are developing the basic NLO molecules, polymeric materials, processes, and devices. These different groups measure and report their results based on different specific and individual tests. There is no accepted test procedure to compare results and compare these to what is needed for a functioning device. Due to the different test procedures and measurement methods employed, it is difficult to make comparisons between the materials. Thus, selecting the most promising development path becomes difficult.

To further compound the problem, results reported in the literature for new materials do not measure all the properties relevant for practical systems. The data reported for new systems can not be compared because no consistent sets of measurements are used. The material development progress for the entire field is thus retarded because of the lack of a consistent test methodology to guide the development of E-O polymers for integrated optics.

2. Objective

The objective for developing an integrated instrumentation is to demonstrate and implement a test procedure that will enhance the development of suitable polymeric E-O materials for integrated optics. The material test requirements are based on the fabrication, assembly, and end use product requirements of the material in a device. The sequential test

procedure is consist of a series of tests designed to efficiently test and screen materials as they are being developed. The test targets a simple integrated optic device to measure a wide range of performance values, while the compatibility of the material is evaluated during the fabrication of the test device. The development of an enhanced material system will demonstrate the usefulness of the procedure. The test methods have been transfer to the material development community.

3. Impact on the new research program of E-O materials at the Northeastern University

This integrated instrumentation has greatly enhanced the capability of the new E-O materials research facility at the Northeastern University to evaluate the E-O material system properties. The new facility established by Professor Alex Jen possesses the capability of performing the electric field induced second harmonic generation (EFISH) measurements for determining the molecular hyperpolarizability ($\beta\mu$) of the NLO chromophores. This facility is also equipped with the instruments such as TGA and DSC for thermal analysis; GPC and HPLC for polymer molecular weight measurement; and Dektak instrument for measuring thin film thickness. In addition, FT-IR and UV-Vis-Near IR spectrometer are used to determine the thermal stability of the E-O polymer thin films. This integrated instrumentation has helped to bridge between the effort of evaluating NLO chromophore molecular studies, and E-O polymeric material system properties, and thus, directly impact the fabrication of waveguide structures for device applications. More than twenty electro-optic materials related papers have been published in the refereed journals based on the characterization results derived from this set-up. In addition, this facility has provided very useful services to researchers (Professor Seth Marder-University of Arizona, Professor Larry Dalton-USC, Professor James Bu-Clark-Atlanta University, and Dr. O. K. Kim-ONR) that are supported by the DoD's funding agency. The capability of this integrated instrumentation includes the spin-coating of uniform polymer thin films, measurements of both TM and TE refractive indices, optical loss, and electro-optic coefficients of poled E-O polymers at various wavelengths of device interest.

4. Interface between the instrumentation and the facility for light-emitting (LED) materials research at the Northeastern University

This integrated instrumentation interfaces very well with the LED materials research facility at Northeastern University (NU) to jointly evaluate organic photonic/opto-electronic material properties. One of the new research program proposed by both professors Alex Jen and Yang Yang (UCLA) aims at demonstrating an integrated all polymer LED/E-O device by using organic conjugated polymers as both a light source (LED) and a photo-detector, and using NLO

polymer channel waveguides as an E-O switching device. This instrumentation greatly enhances the capability of quickly developing/screening E-O materials systems to ensure the greatest chance of success. In the areas of optical and electrical characterization, the micromanupilator device could be used to cure (up to 400 °C) and pole NLO thin films and channel waveguides; Metricon prism coupler could measure refractive index, optical loss, and thickness of polymer thin films; lock-in amplifier and the associated electronic system could measure optical and electro-optic signal generated by LED/E-O materials. This integrated instrumentation will help to bridge between the effort of evaluating E-O and LED polymeric material system properties, and thus, directly impact the fabrication of all polymer LED/E-O devices.

5. Research training of students

The highly interdisciplinary nature of the program to develop high performance E-O materials for device applications, the outstanding faculty and institutions involved, and connections with high technology device companies and DOD laboratories ensure a rich educational environment for the graduate students, postdoctoral, and undergraduate students involved. Students will be active members involved in closely integrated material synthesis, characterization, and device fabrication. Students associated with this program will emerge with a unique background and complement of skills. The ability to communicate with and work with academic, government, and industrial researchers in other disciplines towards a common goal will uniquely qualify them for the technical workforce of the future.

6. Publications that acknowledge the AFOSR

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23. "Thermal Poling of Soda-Lime Glass for hybrid Glass/Polymer Electro-optic Modulators", Y. Enami, P. Poyhonen, D. Mathine, A. Bashar, M. Paratheepan, S. R. Marder, S. Honkanen, B. Kippelen, N. Peyghambarian, A. K-Y. Jen, J. Wu, Appl. Phys. Lett., 2000, **76(9)**, 1086.

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Purchased Equipment

Equipment	Model	Unit Price	Totals	Vender and Address
Lock-in Amplifier SRS Lock-In Amplifier FET Input Preamplifier Bipolar Input Amplifier Transformer Preamplifier Carrying Handle Sub Total	SR850 SR550 SR552 SR554 O760H	\$ 7,500.00 \$ 495.00 \$ 495.00 \$ 995.00 \$ 100.00	**\$ 9,585.00**	Stanford Research Systems 1290-D Reamwood Ave. Sunnyvale, CA 94089 Tel: (408)744-9040 Fax: (408)744-9049
Function Generator Function Generator GPIB and RS-232 Interface High Stability Timebase Sub Total	DS345 Option 01 Option 02	\$ 1,595.00 \$ 495.00 \$ 650.00	**\$ 2,740.00**	
Low Noise Preamplifier Low Noise Preamplifier Sub Total	SR 560	\$ 1,895.00	**\$ 1,895.00**	
Optical Chopper Optical Chopper Replacement Chopper Head Sub Total	SR 540 0540RCH	\$ 995.00 \$ 220.00	**\$ 1,215.00**	
High Voltage Power Supply High Voltage DC Power Supply GPIB Interface Sub Total	PS350 Opt. 01	\$ 1,150.00 \$ 495.00	**\$ 1,645.00**	
High Voltage Supply/Amplifier/Control Sub Total	610C	\$ 4,095.00	**\$ 4,095.00**	Trek 3932 Salt Works Rd. Medina, NY 14103
Compensator Soleil-Babinet Compensator Sub Total	04SBC001	\$ 4,069.00	**\$ 4,069.00**	Melles Griot 1770 Kettering St. Irvine, CA 92714 Tel: (800)835-2626 Fax: (714)261-7589
Polarizers Glen-Taylor Polarizing Prism (2) Prism Holder (2) Sub Total	03PGL301 07HPR003	\$ 726.00 \$ 260.00	**\$ 1,972.00**	
Rotation Control System Rotational Stage Unidex Motion Controller GPIB Card LabVIEW Software Sub Total	ART301 U11x-4-A-vvv LabVIEW	\$ 747.00 \$ 4,885.00 \$ 495.00 \$ 1,995.00	**\$ 8,122.00**	AEROTech 101 Zeta Dr. Pittsburger, PA 15238 Tel: (412)963-7470 Fax: (412)963-7459
Light Sources Diode Laser, 830 nm Diode Laser, 1300 nm Diode Laser, 1550 nm Sub Total	Las-300-830-20 Las-300-1300-20 Las-300-1550-20	\$ 4,500.00 \$ 3,800.00 \$ 4,600.00	**\$ 12,900.00**	Laser Max 3495 Winton Place, Bldg. B Rochester, NY 14623 Tel: (716)272-5420 Fax: (716)272-5427

CV Probing Test Stations				Micromanipulator
Test station	D6	$ 17,050.00		1555 Forrest Way
Accessory		$ 1,000.00		Carson, NV 89706
Sub Total			**$ 18,050.00**	Tel: (702)882-7377
Prism Coupler				Metricon Corporation
Metricon 2010 Prism Coupler	2010	$ 28,500.00		P.O.Box 63
Prism, low index	200-P-1	$ 750.00		Pennington, NJ 08534
Prism, high index	200-P-2	$ 750.00		Tel: (609)737-1052
Prism, broad index	200-P-3	$ 750.00		Fax: (609)737-1567
Prism, broad index	200-P-4	$ 750.00		
TM mode option	2010-TM	$ 1,250.00		
Non-contact thickness	2010-VO	$ 3,000.00		
measurement	2010-NSW-1550	$ 5,200.00		
Diode laser, nominal 1550 nm	2010-NSW-1300	$ 3,800.00		
Diode laser, nominal 1300 nm	2010-NSW-830	$ 4,000.00		
Diode laser, nominal 830 nm	2010-SBL-IR	$ 1,500.00		
Secondary Input Port	2010-GE	$ 1,200.00		
Germanium Detector	2010-WGL2	$ 5,300.00		
Waveguide loss measurement				
option				
Sub Total			**$ 56,750.00**	
Optical Table				Newport Corporation
Optical Table	RS3000-512-12	$ 11,775.00		1791 Deere Ave.
Table legs (4)	I-2000	$ 3,455.00		Irvine, CA 92714
Overhead Table Shelf System	ATS-12	$ 2,091.00		Tel: (800)222-6440
Sub Total			**$ 17,321.00**	Fax: (714)253-1680
Spin Coater (cost shared)				Solitec, Inc.
Single-head coater	5110-CT	$ 22,070.00		3901 Burton Dr.
Sub Total			**$ 22,070.00**	Santa Clara, CA
				95054
		Total Equipment Cost	**$ 162,429.00**	
		COST SHARE	**$ (22,070.00)**	
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